

Abstract – Electromagnetic Interference/Compatibility (EMI/EMC) Control Test and Measurement Facility

Test process, milestones and inputs are unknowns to first-time users of the EMI/EMC Test Facility. The User Test Planning Guide aids in establishing expectations for both NASA and non-NASA facility customers. The potential audience for this guide includes both internal and commercial spaceflight hardware/software developers. It is intended to assist their test engineering personnel in test planning and execution. Material covered includes a roadmap of the test process, roles and responsibilities of facility and user, major milestones, facility capabilities, and inputs required by the facility. Samples of deliverables, test article interfaces, and inputs necessary to define test scope, cost, and schedule are included as an appendix to the guide.

Electromagnetic Interference/Compatibility (EMI/EMC) Control Test and Measurement Facility

User Test Planning Guide



National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

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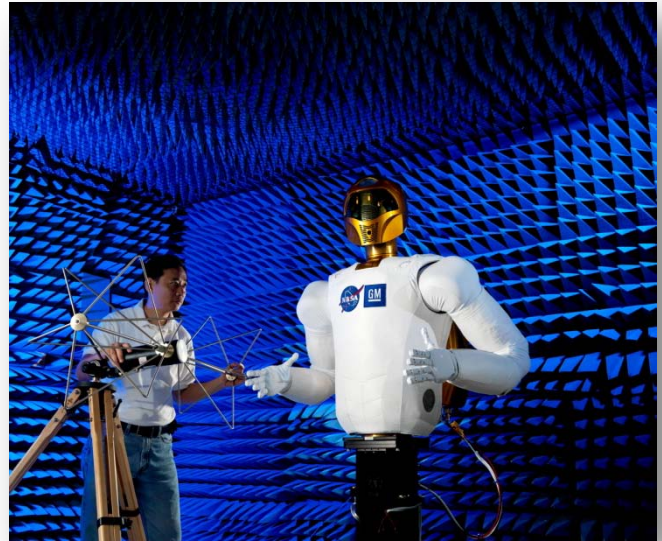
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1.0 Electromagnetic Interference/Compatibility Test Facility

The Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) Control Test and Measurement Facility supports engineering development and EMI/EMC measurements and provides EMI/EMC evaluation and certification testing of crew, flight, and ground support equipment including, but not limited to, Communication, Instrumentation, Biomedical, Guidance and Navigation, Computation, and Robotics.

Services Provided

- Testing - developmental, engineering support, performance and precertification evaluation, and certification testing
- Conducted and radiated emissions and susceptibility testing (e.g., MIL-STD-461, all revisions; RTCA/DO-160, sections 16 through 21)
- Lightning indirect effects and Electrostatic Discharge (ESD) assessment (e.g., RTCA/DO-160, sections 22 and 25)
- Cable transfer impedance and equipment shielding effectiveness assessment
- EMC design consultation
- Detailed test planning support and test data collection/reporting



Capabilities

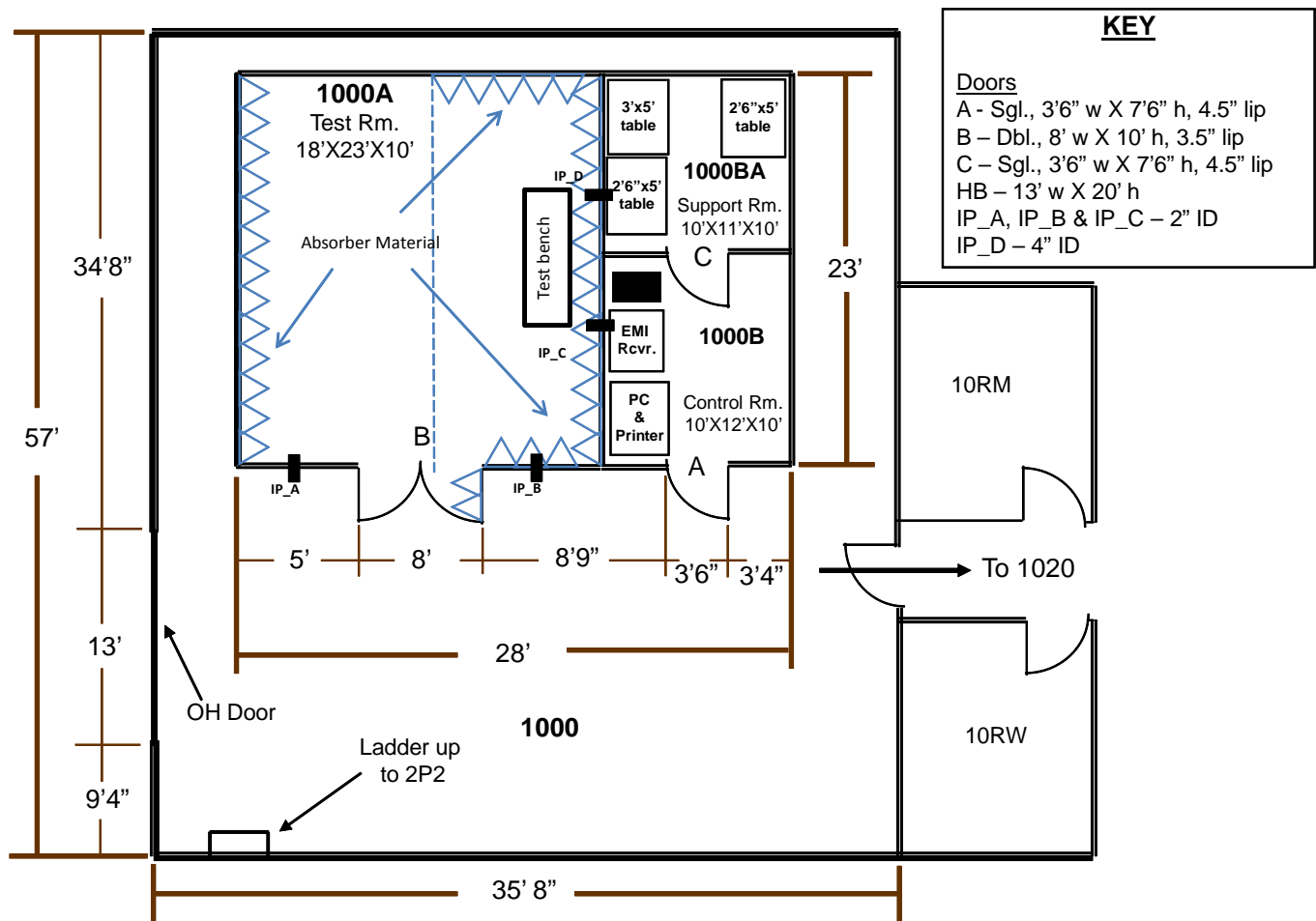
Shielded room enclosures	Meet military standard MIL-STD-285
Synthesized signal generators	Capable of covering a frequency range of 10 Hz to 26 GHz
Radio frequency (RF) power amplifiers	Provide up to 500 W of output power in the frequency range of 10 kHz to 18 GHz
Lightning transient generator and support probes	Provide test waveforms 1, 3A, 3B, 4, and 5A for lightning indirect effects testing up to Level 3
ESD test equipment	Provides standard ESD test waveforms up to a 30 kV peak pulse voltage
Complete line of general purpose ancillary test equipment	Power supplies, oscilloscopes, power meters, and voltmeters
High-fidelity EMC modeling software	General purpose three-dimensional electromagnetic modeling

Point of Contact

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2.0 Facility Layout

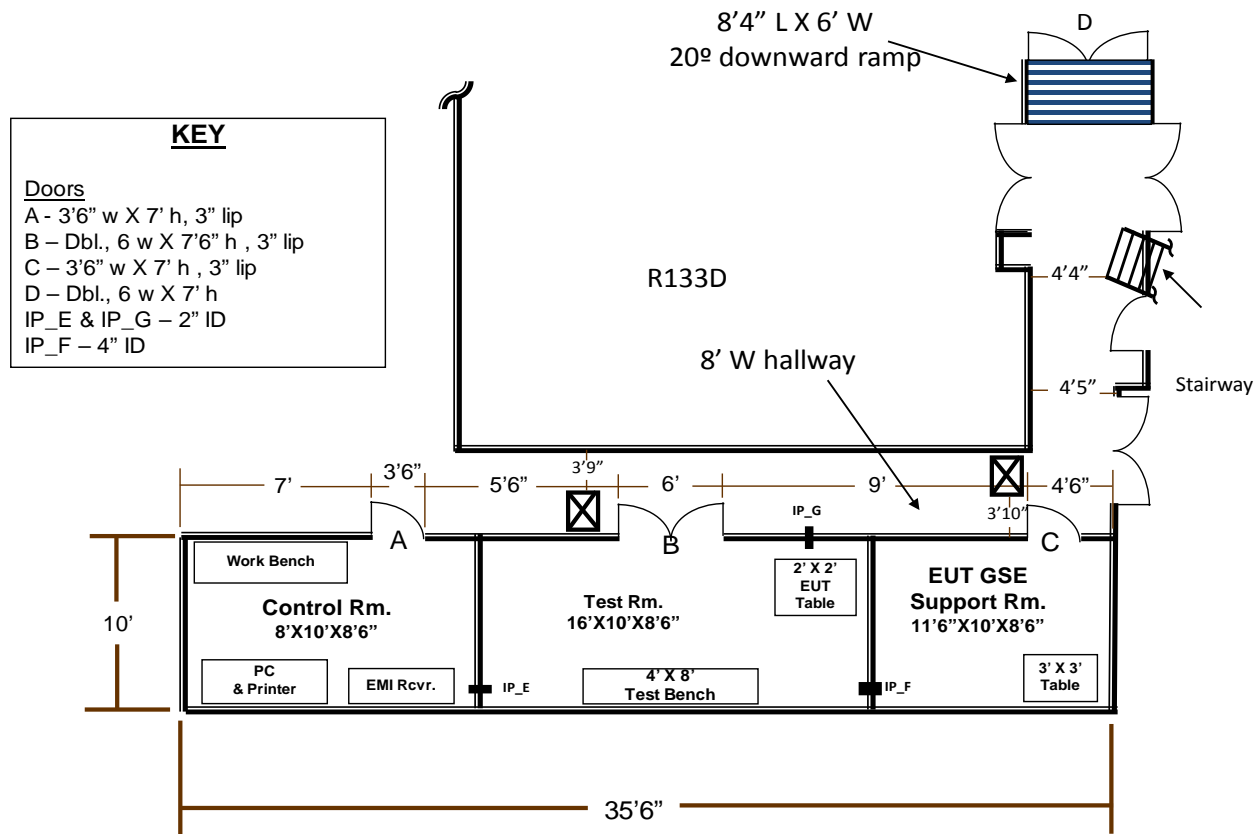
The facility has two shielded enclosures, or chambers, as shown in the accompanying figures. The primary chamber is designed to accommodate larger pieces of equipment. The wall, ceiling, and floor are constructed of panels of 24-gauge galvanized steel sheets laminated to both sides of a ¾-inch structural core. The floors are covered with tile and are designed to handle a loading capacity of 1,000 lb. per square foot. Each chamber is equipped with a 9' W x 3' D ground plane bench, covered with a copper sheet that is electrically bonded to the adjacent wall. The test benches stand 30 inches above the floor.



NOTE: The walls and ceiling of the test room are treated with ferrite tiles and absorber material out to the dotted line and across the back wall. Test Bench can be removed or another may be added as needed to accommodate hardware.

Physical Layout of EMI/EMC Primary Facility in B14A/R1000 High Bay

Large Equipment Under Test (EUT) can be accommodated in the primary chamber via the 13'-wide rollup High Bay door in Johnson Space Center (JSC) Building 14A, Room 1000. Heavy EUT can be handled with a forklift or crane, operated by local riggers. EUT too large to fit on the ground plane table may be accommodated by removal of the ground plane bench. Ramps are available so that EUT can be easily moved inside over the 3.5" chamber doorway threshold. Handling of fixtures, test item placement, and service connections should be resolved during pretest coordination and planning.



Physical Layout of EMI/EMC Secondary Chamber in B14/R133D

* See Appendix A for facility interface information and Appendix E for sample test configurations.

3.0 Safety and Health

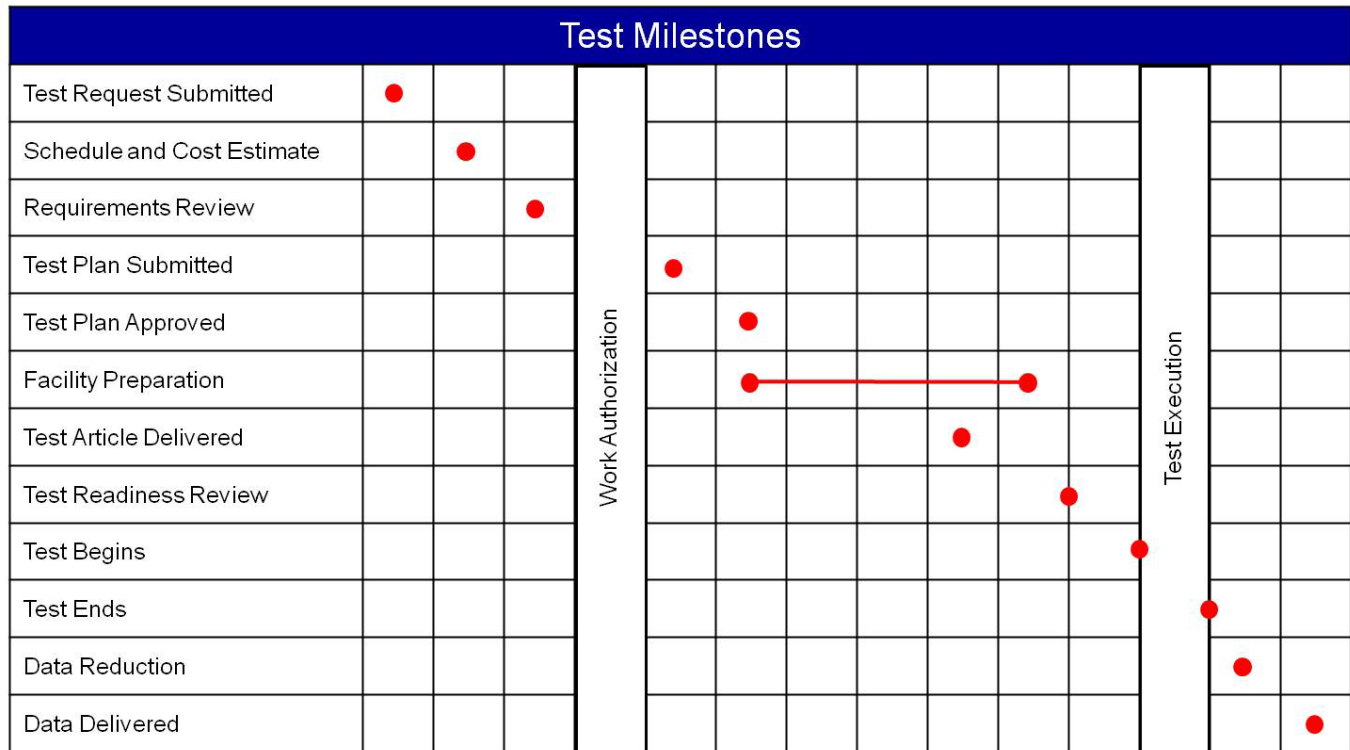
Safety is an integral part of the culture at the National Aeronautics and Space Administration (NASA). Management, leadership, and employee involvement from all organizations are critical to the success of NASA's safety program. In order to ensure personal safety and a safe test environment throughout the process, the requester shall furnish the facility with the information necessary to perform a hazard assessment of the test article. Additionally, while visiting JSC, the requester shall follow all facility-specific safety and health requirements. A facility safety briefing shall be provided to all personnel prior to the start of the test. The safety briefing will include a review of the laboratory safety rules, potential hazards, and emergency procedures.

4.0 Test Process Flow

The flowchart presented below outlines the basic roadmap and significant milestones between the initial test request and delivery of test data. The flow is separated between Test Requester actions and Facility actions, highlighting interactions and inputs between the Test Requester and the facility Test Director.



The test schedule is highly dependent on the complexity of the test, facility availability, and sequence of runs. For time-critical testing, it may be possible to accelerate the schedule, given constraints associated with previous customer commitments. A detailed schedule shall be developed as part of the test planning process following a review of the test objectives and requirements. Typical major milestones are presented below:



Note: The schedule is subject to the complexity of test requirements.

4.1. Proprietary Information

The EMI/EMC Test Facility provides for protection of proprietary information and hardware throughout the test process. The Test Requester shall clearly mark all export controlled or proprietary hardware items and data provided with a notice of restriction on disclosure or usage. The Test Director shall safeguard export controlled or proprietary items from unauthorized use and disclosure and ensure that test articles remain secure within the facility and are properly sequestered. Hardware items shall be returned to the Test Requester or disposed of in accordance with the Test Requester's instructions at the completion of the test activity.

4.2 Test Initiation Phase

The test initiation phase establishes the relationship between the Test Requester and the Test Director. The Test Requester shall provide a test request to the Test Director. The test request will be used to determine test feasibility and to develop an estimated cost and a preliminary test schedule. An initial requirements review meeting may be necessary in order to discuss the characteristics of the test article, the test approach, or any special considerations for the test. An onsite tour of the facility is highly recommended for familiarization and to provide an opportunity for an exchange of technical information.

Inputs: Test Requester provides test request, identifies Test Article Expert
Activities: Facility Test Director reviews test request to determine test feasibility
Outputs: Facility delivers preliminary test plan, estimated cost and schedule to Test Requester

4.2.1 Test Request

The test request outlines the EUT requirements, test objectives, test article description, and preferred schedule. A Test Request Worksheet is provided in Appendix B. This worksheet addresses the basic requirements for testing in the EMI/EMC Test Facility. It is suggested that the Test Requester complete this worksheet to facilitate the development of a preliminary test plan. At a minimum, the test request should include the following information:

Test Requirements and Objectives

A brief description of the test requirements including, but not limited to, the following:

- Applicable EMI/EMC requirements/limits/specification (e.g., customer specification, MIL-STD-461, DO-160)
- Desired test environment and modes of operation
- Proposed test approach
- Test data requirements

Test Article Description

A brief description of the test article including, but not limited to, the following:

- Size/dimensions (provide drawings, sketches, photos)
- Weight
- Test article interface (electrical, mechanical, fluids, gases, pressure, temperature, other)
- Special considerations [hazards, cleanliness, compatibility, Material Safety Data Sheets (MSDS)]
- Handling, storage, and security requirements

Schedule

Identify the desired start date and the required date for delivery of the data/test report.

4.2.2 Schedule and Cost Estimate

A preliminary cost and schedule estimate, including major milestones, will be delivered following review of the Test Request Worksheet. Additional details and refinement of the cost and schedule estimate will be worked out with the Test Requester as test planning proceeds, with a final version to be agreed upon prior to the Test Readiness Review (TRR).

4.3 Test Preparation Phase

The detailed test plan and test schedule are finalized during the test preparation phase. The Test Requester shall provide detailed test requirements and test article documentation to the Test Director. A TRR will be held following approval of the test plan.

Inputs:	Test Requester provides test requirements and objectives, and test article documentation
Activities:	Facility and Test Requester develop test plan Facility begins assembly of facility-unique interface/support structure(s) (if needed) Test Requester ships/transport test article and associated support/peripheral equipment to JSC
Outputs:	Test Requester approves test plan, schedule, and final cost estimate Facility hosts TRR

4.3.1 Test Requirements

A complete understanding of test requirements and facility capabilities is mandatory for a successful test. Test requirements must be carefully defined and reviewed so that the test team understands the effect of the requirements on test facility preparation and test performance. The Test Requester shall provide a detailed list of test requirements including, but not limited to, the following:

- Applicable EMI/EMC requirements/limits/specifications (e.g., customer specification, MIL-STD-461, DO-160)
- Desired test conditions (frequency) and modes of operation
- Proposed test approach
- Test data requirements
- Test article interface
 - Orientation, load points, method of suspension or test article support
 - Electrical, mechanical, fluids, gases, pressure, temperature, other
- Data/instrumentation requirements (provided by Test Requester and facility)

4.3.2 Test Article Documentation

Test Article Drawings

The Test Requester shall provide detailed test article drawings as requested by the facility. Test article drawings are used to prepare the facility interfaces, test article support structures, and instrumentation connection points.

Material Safety Data Sheets

NASA must ensure that all materials exposed to test environments do not present a hazard to personnel or the test facility. The Test Requester shall deliver to the facility MSDS for materials used in the construction or operation of the test article and any associated support equipment. The Test Director will review the materials list for compatibility with the test environment.

Test Article Hazard Identification

The safety of facility personnel, facility equipment, and the test article is imperative to NASA. Potential hazards, material compatibility, and facility interfaces will be reviewed with the facility prior to testing. In certain instances, special precautions must be taken due to the severity level of these potential hazards. The Test Requester may be asked to provide further information to clarify or mitigate a potential hazard. A Test Article Hazard Checklist is provided in Appendix B.

4.3.3 Test Plan

A test plan will be prepared through collaboration between the Test Director and the Test Requester. The final test plan shall be jointly approved by the Test Requester and the Test Director prior to the TRR. The test plan will be the controlling document, with respect to scope and approach for the test program. The test plan will include, at a minimum, the scope, test article description, test objectives, test requirements/limits, safety considerations, data requirements, and detailed test procedures. Changes to the test plan that occur after the TRR that result in a major change to the scope of the test or that present new hazards will require a delta TRR.

4.3.4 Test Schedule

A detailed schedule shall be developed jointly by the Test Director and the Test Requester. The schedule shall allow adequate time for creation, review, and approval of test plans, assembly of facility interfaces/structures, test article delivery, performance of the test, and creation of the test report. The schedule of other tests and maintenance activities will be reviewed for potential conflicts. Any identified conflicts shall be resolved prior to the TRR.

4.3.5 Test Article Delivery

The test article delivery date will be determined on a case-by-case basis. An agreed-upon delivery date shall be captured as a milestone in the test schedule. The Test Requester is expected to provide personnel to handle and set up hardware prior to the start of the test. The test article shall be secured within the test facility, unless directed to provide another means of storage. A physical inspection of the test article shall be performed by the Test Director and a functional test of the test article shall be performed by the Test Article Expert prior to the start of testing. Test Article Expert participation is mandatory throughout all test phases in order to provide immediate feedback on test article handling and any integration issues that arise.

4.3.6 Test Readiness Review

A TRR will be held to ensure the completion of all necessary facility and test article activities prior to test execution. The TRR will include the following:

- Review of the test plan, test procedures, and other required test documentation
- Confirmation of facility and test article readiness
- Review of configuration records, including facility interface control documents, pressure system certification, instrumentation calibration, and materials compatibility
- Assurance that controls are in place to mitigate risks or hazards identified in the Test Article Hazard Analysis

- Verification that data acquisition and processing functions are in place to adequately capture all critical data
- Confirmation that multimedia coverage is adequate to provide recognition and assessment of potential test anomalies

Approval to proceed with test operations is granted by the Test Readiness Review Board (TRRB). The Test Director shall ensure that all TRR actions have been accomplished prior to the start of the test. The TRRB shall convene 1 to 5 business days prior to the start of the test. TRRB participants shall include the following:

NASA TRRB Chairman	Test Article Expert
Test Director	Safety Engineer
Test Safety Officer	Quality Engineer – if required by facility

Other expertise (e.g., pressure safety, radiation control, crew office, medical) may be required for support, depending on the nature of the EUT.

4.4 Test Execution Phase

NASA encourages Test Requester participation in the testing activity. The Test Requester shall provide a Test Article Expert to verify that test setup and execution meet the stated requirements and objectives. The Test Article Expert also shall verify test article performance and approve requested test deviations during test operations.

Inputs: Approval to begin testing received from TRRB

Activities: Facility conducts testing activity

Outputs: Test data package and/or detailed test report

4.4.1 Test Authority

The Test Director has the authority and responsibility to direct the test in accordance with the approved test plan and to terminate test activities per the test plan when danger is imminent or test control cannot be maintained. The Test Director will ensure that positive actions are taken to halt any steps in the test procedure whenever unsafe or hazardous test conditions arise. The Test Director, with the concurrence of the Test Requester, has the authority to terminate the test when sufficient data has been obtained to meet objectives or when it is determined that objectives cannot be met. Test team personnel will accept directions only from the Test Director or the Test Director's management.

4.4.2 Test Deviations

Changes to the test procedure shall be approved jointly by the Test Requester and the Test Director. Deviations that result in a major change to the scope of the test or that present new hazards shall require a delta TRR.

4.5 Test Closeout Phase

Either the data package or a detailed test report shall be delivered to the Test Requester within 15 business days following completion of testing. The Test Requester shall notify the Test Director upon receipt. Acceptance of the test data concludes the test activity.

Inputs: Completed test

Activities: Facility ships/transport test article to Test Requester

Test Director delivers data package or detailed test report to the Test Requester

Outputs: Test Requester accepts data

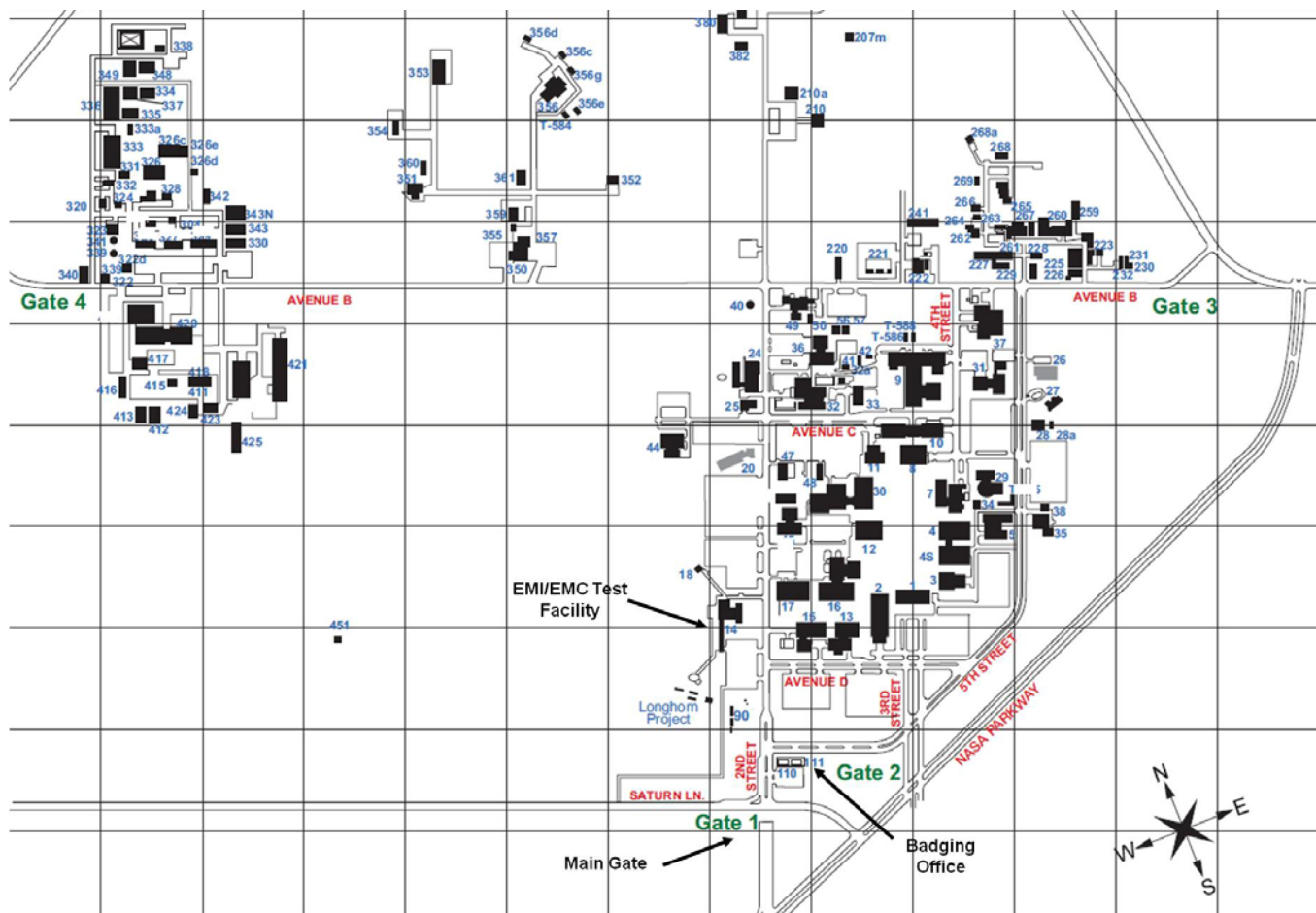
4.5.1 Customer Feedback

JSC encourages feedback from our customers. Evaluation of the services we provide enables continued improvement to our process. Please provide any feedback on our services to the Laboratory Manager following receipt of the test data. Your feedback is greatly appreciated.

5.0 Facility Access

Identification badges are required for all persons requiring access to JSC. The Test Director or designee will initiate a badge request for all Test Requester personnel who will be participating in the test activity. Badge requests must be submitted at least 4 days prior to the visit to prevent badge processing delays. Badge requests for non-U.S. citizens may require a minimum of 30 business days to process. Test Requester personnel shall arrive at JSC Building 110 to pick up temporary identification badges. Visitors to JSC must show a current picture identification (valid driver's license, U.S. passport, government ID card).

The EMI/EMC Test Facility is located in JSC Building 14. A facility access briefing shall be provided to the Test Requester personnel requiring unescorted access to the facility prior to the start of the test. All other personnel requiring entry must be escorted by a person approved for access. Access to the facility is controlled through a cipher lock.



6.0 Roles and Responsibilities

Lab Manager – Responsible for operations of the facility. The Lab Manager is the initial point of contact for the Test Requester.

Test Director – Has overall responsibility for all phases of the test process.

Test Requester – The client requesting performance of a test activity. The Test Requester is responsible for the test article and for providing a Test Article Expert.

Test Article Expert – A representative of the Test Requester with thorough knowledge of the test article and how it is to be operated in the test environment. The Test Article Expert also is responsible for approving the test plan and verifying that test objectives are met.

Test Conductor – Assigned under the authority of the Test Director to execute the test in accordance with the approved test plan.

Test Safety Officer – Monitors and approves all hazardous operations for the test. The Test Safety Officer has the authority to recommend the discontinuance of test operations considered unsafe.

Safety Engineer – Reviews the Test Article Hazard Checklist and generates the integrated hazard analysis for the test facility to identify any additional hazards that could result in injury to personnel.

Facility Quality Engineer – Responsible for verifying that the test facility is ready for the test by ensuring that all constraints to the test have been closed.

Responsibilities Matrix

Item	Test Requester	Facility
Test Request Worksheet	Create	Review and provide assistance as needed
Cost and schedule	Joint creation/approval	Joint creation/approval
Hazards	Identify test article hazards	Create test article/facility integrated hazard analysis
Test plan	Joint creation/approval	Joint creation/approval
Test Readiness Review	Joint approval	Conduct review and provide joint approval
Test execution	Verify test article performance Verify that test setup and execution meet objectives Approve requested deviations	Execute test
Test data/results	Notify Test Director of data package or detailed test report receipt and acceptance	Deliver to Test Requester
Shipping	Provide instruction	Execute per request

Acronyms

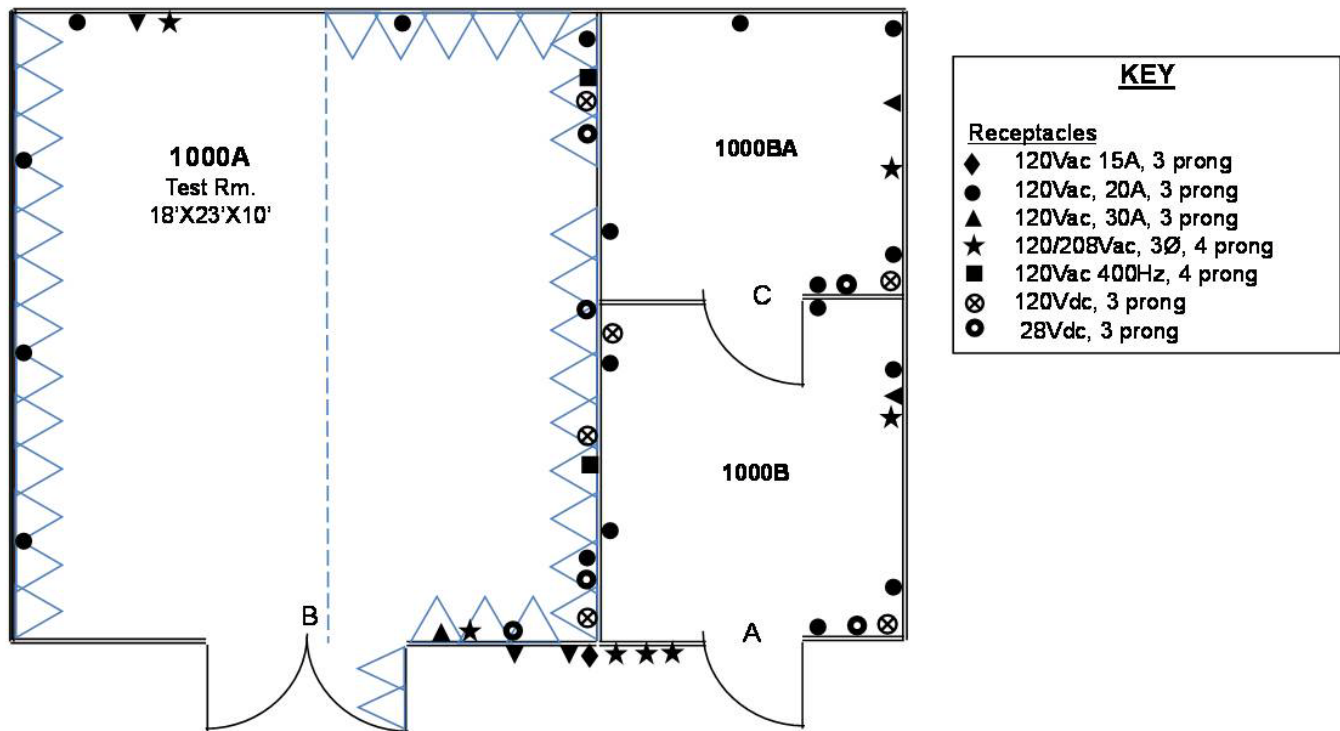
μF	Microfarad(s)
A	Ampere(s)
AC	Alternating Current
CCTV	Closed-Circuit Television
dB	Decibel(s)
DC	Direct Current
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
EUT	Equipment Under Test
GHz	Gigahertz
Hz	Hertz
IR	Infrared
JSC	Johnson Space Center
kHz	Kilohertz
kV	Kilovolt(s)
lb	Pound(s) LISN Line Impedance Simulation or Stabilization Network
LSC	Line Stabilization Capacitor
MHz	Megahertz
MSDS	Material Safety Data Sheets
NASA	National Aeronautics and Space Administration
P/N	Part Number
RF	Radio Frequency
TLRS	Test Lead Routing Standard
TRR	Test Readiness Review
TRRB	Test Readiness Review Board
UV	Ultraviolet
W	Watt(s)

Appendices

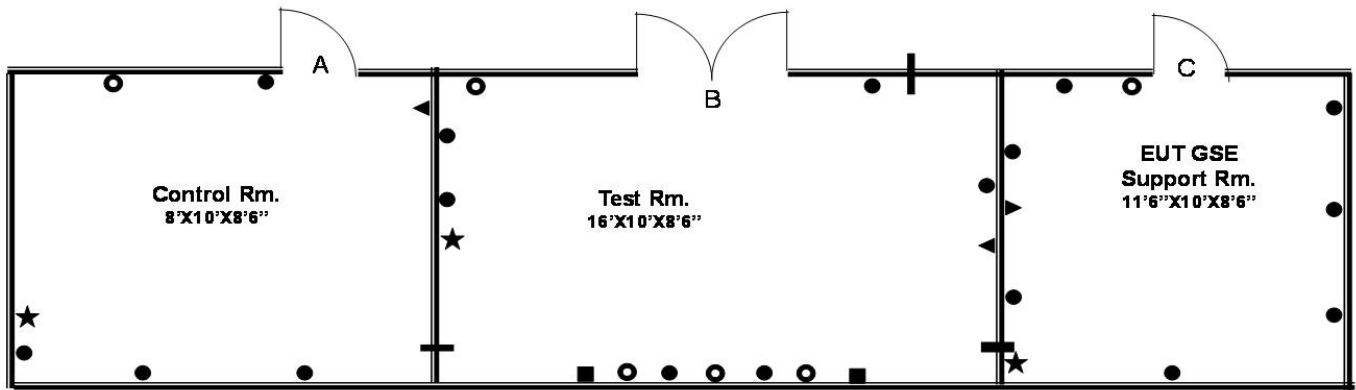
- A. Facility Interfaces
- B. Test Request Worksheet
- C. Facility Specifications
- D. Facility Equipment
- E. Sample Test Configurations

Appendix A Facility Interfaces

The EMI/EMC Test Facility consists of a primary and a secondary laboratory. The primary EMI/EMC laboratory is located in Building 14, Annex High Bay, Room 1000. The secondary EMI/EMC laboratory is located in Building 14, Room 133D.



EMI/EMC Laboratory B14A/R1000 High Bay Electrical Outlet Locations



<u>KEY</u>	
<u>Receptacles</u>	
●	120Vac, 20A, 3 prong
▲	120Vac, 30A, 3 prong
★	120/208Vac, 3Ø, 5 prong
■	120Vac 400Hz, 4 prong
○	28Vdc, 3 prong

EMI/EMC Laboratory B14/R133D Electrical Outlet Locations

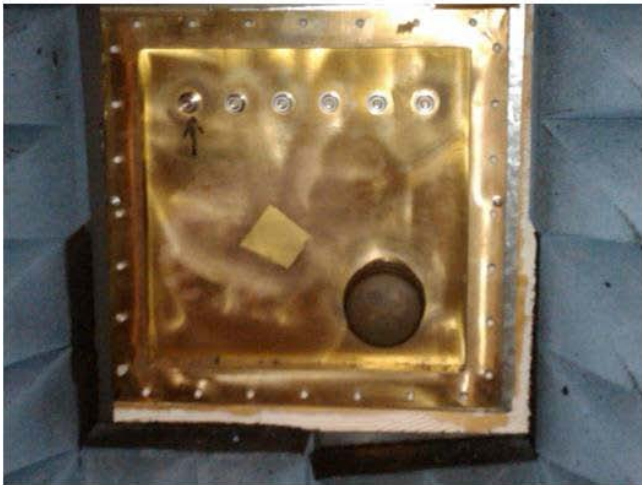
During EMI tests, the doors of the test room shielded enclosures are closed. Access for cables to the EUT is provided by interface panels, as shown below. Through these interface panels, control and monitor equipment may be connected to the EUT. Interface panels are constructed of a grounded metal bulkhead with fiber optic, N-type cable connectors and pipe ports.



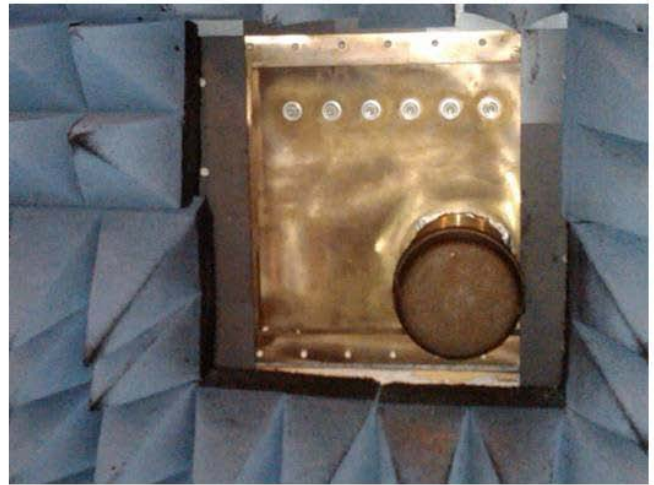
IP_A



IP_B



IP_C



IP_D

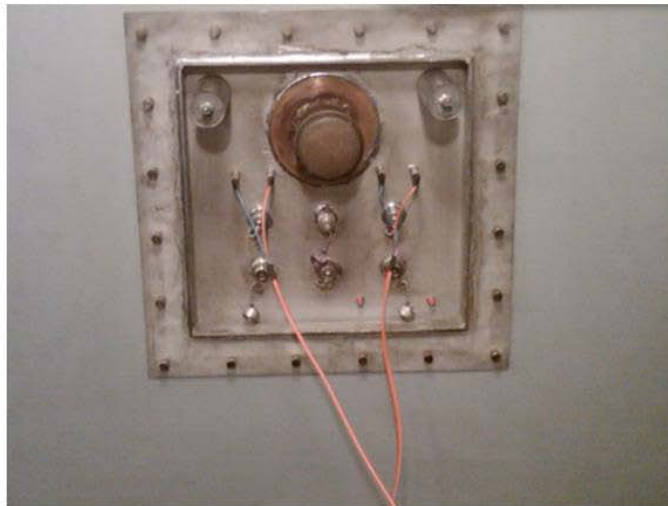
Interface Panels in the EMI/EMC Laboratory B14A/R1000 High Bay



IP_E



IP_F



IP_G

Interface Panels in the EMI/EMC Laboratory B14/R133D

Appendix B Test Request Worksheet

Test Requester Information

Test Article Expert:	Contact Information (Phone, E-mail, Address):
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Test Objectives

Purpose of Test:	
Proposed Test Start Date:	Critical Test Start Date:

Test Article

Test Article Description:	
Physical Dimensions (L/W/H):	
Weight:	Test Article Setup Time:
Support/Ancillary Equipment Provided by Test Requester:	

Test Article Handling Requirements

Cleanliness Level:	Controlled Access:
Special Moving/Handling:	

Power Requirements

Input Voltage Type (AC, DC, Both):	Input Voltage Requirement (Volts):	
Input Power (Watts or Amps):	Number of Power Connections:	Power Phase:

Test Requirements

Ground Plane Requirements (Conductive/Non-Conductive Table, Requester-Provided):
Test Article Interface (e.g., support structure, connectors):
EMI Specification(s) To Be Met (specific standards, i.e., MIL-STD-461):

Instrumentation

List the primary measurements to be made (e.g., frequency voltage, amplitude):

Additional Information

List any other information pertinent to the test:

Test Article Hazard Checklist

A hazard analysis statement is required for any of the following applicable attributes of any of your provided hardware (e.g., test article, support equipment).

Hazard	Y	N	Comments
Mechanical	<input type="checkbox"/>	<input type="checkbox"/>	
Handling (> 40 lb or > 4 ft in any dimension)	<input type="checkbox"/>	<input type="checkbox"/>	
Instability	<input type="checkbox"/>	<input type="checkbox"/>	
Sharp Edges	<input type="checkbox"/>	<input type="checkbox"/>	
Pinch Points	<input type="checkbox"/>	<input type="checkbox"/>	
Exposed Mechanisms (e.g., rotating, reciprocating)	<input type="checkbox"/>	<input type="checkbox"/>	
Pressure Systems	<input type="checkbox"/>	<input type="checkbox"/>	
Stored Energy (e.g., springs, weights, flywheels)	<input type="checkbox"/>	<input type="checkbox"/>	
Ejected Parts, Projectiles	<input type="checkbox"/>	<input type="checkbox"/>	
Electrical	<input type="checkbox"/>	<input type="checkbox"/>	
Voltage (> 50 volts)	<input type="checkbox"/>	<input type="checkbox"/>	
Batteries (type and number)	<input type="checkbox"/>	<input type="checkbox"/>	
Generation/Storage (e.g., coils, magnets, capacitors)	<input type="checkbox"/>	<input type="checkbox"/>	
Electrostatic Sensitive Devices	<input type="checkbox"/>	<input type="checkbox"/>	
Thermal	<input type="checkbox"/>	<input type="checkbox"/>	
Hot Surfaces (> 113 °F, 45 °C)	<input type="checkbox"/>	<input type="checkbox"/>	
Heaters	<input type="checkbox"/>	<input type="checkbox"/>	
Cold Surfaces (< 39 °F, 4 °C)	<input type="checkbox"/>	<input type="checkbox"/>	
Cooling Devices	<input type="checkbox"/>	<input type="checkbox"/>	

Hazard	Y	N	Comments
Radiation	<input type="checkbox"/>	<input type="checkbox"/>	
Ionizing	<input type="checkbox"/>	<input type="checkbox"/>	
Non-Ionizing	<input type="checkbox"/>	<input type="checkbox"/>	
Laser	<input type="checkbox"/>	<input type="checkbox"/>	
Microwave	<input type="checkbox"/>	<input type="checkbox"/>	
Infrared (IR)	<input type="checkbox"/>	<input type="checkbox"/>	
Ultraviolet (UV)	<input type="checkbox"/>	<input type="checkbox"/>	
Radio Frequency (RF)	<input type="checkbox"/>	<input type="checkbox"/>	
Visible Light, High Intensity	<input type="checkbox"/>	<input type="checkbox"/>	
Material	<input type="checkbox"/>	<input type="checkbox"/>	
Uncontained Brittle Materials	<input type="checkbox"/>	<input type="checkbox"/>	
Contained Fluids	<input type="checkbox"/>	<input type="checkbox"/>	
Toxic, Corrosive, Flammable Fluids	<input type="checkbox"/>	<input type="checkbox"/>	
Biohazards	<input type="checkbox"/>	<input type="checkbox"/>	
Miscellaneous	<input type="checkbox"/>	<input type="checkbox"/>	
Noise Level (> 85 dBA)	<input type="checkbox"/>	<input type="checkbox"/>	
Ultrasonic	<input type="checkbox"/>	<input type="checkbox"/>	
Pyrotechnics/Explosives	<input type="checkbox"/>	<input type="checkbox"/>	

Appendix C Facility Specifications

Specifications

Measurement Bandwidths

The measurement bandwidths used for emissions testing are stored in the EMI test software. Measurement bandwidths are unique for narrowband and broadband frequency ranges. The displayed narrowband measurement data reflects the use of the narrowband measurement bandwidths. The displayed broadband measurement data reflects a 1 MHz normalized bandwidth. The following is a sample of bandwidths offered by the EMI/EMC Control Test and Measurement Facility. The facility can accommodate a wide range of bandwidths, including most bandwidths cited in MIL-STD-461F.

Narrowband Radiated Emission Measurement Bandwidths

Frequency Range (MHz)	Bandwidth (kHz)
0.014 – 0.1	1
0.1 – 25	3
25 – 200	10
200 – 1,000	30
1,000 – 10,000	30
1,770 – 2,300	10

Broadband Radiated Emission Measurement Bandwidths

Frequency Range (MHz)	Bandwidth (kHz)
0.014 – 0.1	3
0.1 – 25	10
25 – 200	1
200 – 1,000	1
1,000 – 10,000	300
1,770 – 2,300	300

AC Magnetic Field Radiated Emission Measurement Bandwidths

Frequency Range (MHz)	Bandwidth (kHz)
$3.E^{-5}$ – 0.001	10
0.001 – 0.01	30
0.01 – 0.05	300

Conducted Emission Measurement Bandwidths

Frequency Range (MHz)	Bandwidth (Hz)
$3.E^{-5}$ – 0.001	10
0.001 – 0.01	100
0.01 – 0.02	1,000
0.015 – 0.5	3000
0.5 – 50	10,000

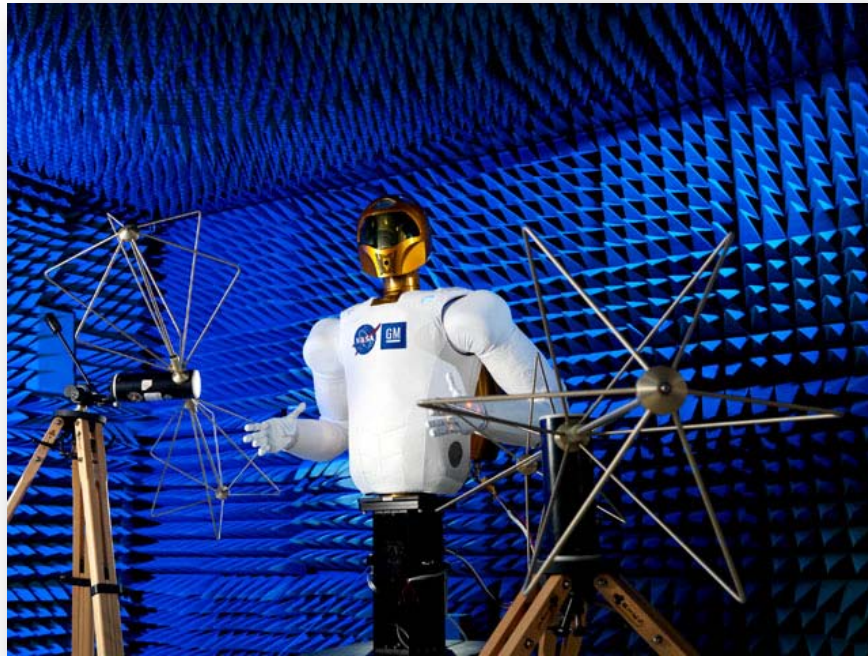
Appendix D Facility Equipment

- 50 Ohm (Ω), Coaxial Load
- 500 Ω 50 W Resistor
- Agilent 11975A Amplifier (2 GHz – 8 GHz)
- Agilent 33120A Function Generator
- Agilent 8449B Preamplifier (1 GHz – 18 GHz)
- Agilent E4419B Power Meter
- AH Systems SAS-200/550-1 Rod Antenna (14 kHz – 25 MHz)
- AH Systems SAS-200/560 5-Inch Loop Antenna (30 Hz – 50 kHz)
- Ailtech Model 15100 (500 MHz – 1000 MHz)
- Ailtech Model 20512 (150 MHz – 500 MHz)
- Amplifier Research 200W1000M7 Amplifier (80 MHz – 1 GHz)
- Amplifier Research FM5004 Field Monitor
- Amplifier Research FP2000 Field Probe (10 kHz – 1 GHz)
- Amplifier Research FP2080 Field Probe (80 MHz – 40 GHz)
- Amplifier Research FP5000 Field Probe (10 kHz – 1 GHz)
- Amplifier Research FP5034 Field Probe (300 MHz – 40 GHz)
- Amplifier Research FP5080 Field Probe (80 MHz – 40 GHz)
- Amplifier Researches E-filed Generator (14 kHz – 30 MHz)
- Amplifier Researches Log Periodic Antenna (200 – 1000 MHz)
- Avtech AV1015B Pulse Generator
- Boonton 92A Millivoltmeter
- Boonton 93A True RMS Millivoltmeter
- Current Probe Calibration Fixtures
- Eaton Ailtech 93490 -1 Conical Log Spiral Antenna (200 – 1000 MHz)
- Electro-Metrics EM-6980 Current Probe (20 Hz – 50 kHz)
- Electro-Metrics EM-6981 Current Probe (9 kHz – 110 MHz)
- Electro-Metrics PCL-11 Current Probe (30 Hz – 50 kHz)
- Electro-Metrics PCL-30 Current Probe (9 kHz – 110 MHz)
- EMC-20-Ammeter
- EMC-21-10A LISN (power lines carrying less than 6 A)
- EMC-21-50A LISN (power lines carrying from 6 – 50 A)
- EMCO 3104C Biconical Antenna (20 – 200 MHz)
- ETS 3106 Double Ridged Horn (200 MHz – 2 GHz)
- ETS 3115 Double Ridged Horn (1 GHz – 18 GHz)
- ETS 3117 Double Ridged Horn (1 GHz – 18 GHz)
- F. W. Bell 6010 Gaussmeter With Probe
- F. W. Bell 9500 Gaussmeter With Probe
- Fluke Digital Voltmeter
- Hewlett Packard 200CD Audio Oscillator
- Hewlett Packard 33120A Function Generator

- Hewlett Packard 436A Power Meter
- Hewlett Packard 438A Power Meter
- Hewlett Packard 651A Test Oscillator (10 Hz – 10 MHz)
- Hewlett Packard 8447 Preamplifier (100 kHz – 1.3 GHz)
- Hewlett Packard 8562A Spectrum Analyzer (40 Hz – 22 GHz)
- Hewlett Packard 8566B Spectrum Analyzer (30 Hz – 22 GHz)
- Hewlett Packard 8582B Automatic Spectrum Analyzer System
- Hewlett Packard 8663A Signal Generator (150 kHz – 2.0 GHz)
- Hewlett Packard 8672A Signal Generator (2.0 GHz – 18 GHz)
- Hewlett Packard 8673B Signal Generator (2.0 GHz – 26 GHz)
- Hewlett Packard E7405A (9 kHz – 26.5 GHz)
- High-Pass Filters, Low-Pass Filters, Single-Frequency Rejection Networks, and Broadband Attenuators
- Hughes TWTA (1000 MHz – 2000 MHz)
- Hughes TWTA (2000 MHz – 4000 MHz)
- IFI CMC250 Amplifier (80 MHz – 1 GHz)
- IFI SCCX100 Amplifier (10 kHz – 250 MHz)
- IFI SCCX75 Amplifier (10 kHz – 220 MHz)
- IFI SMX10 Power Amplifier (10 kHz – 1 GHz)
- IFI T1875-500 Amplifier (7.5 GHz – 18 GHz)
- IFI T251-500 Amplifier (1 GHz – 2.5 GHz)
- IFI T7525-500 Amplifier (2.5 GHz – 7.5 GHz)
- Test Signal Monitor Network Model JSF- 3
- JSF-2 Coupling Capacitor Network
- LeCroy 9310AM Oscilloscope
- LeCroy LT374 Oscilloscope
- LogiMetrics A600/C Amplifier (4 GHz – 8 GHz)
- LogiMetrics A600/L Amplifier (1 GHz – 2 GHz)
- LogiMetrics A650/S Amplifier (2 GHz – 4 GHz)
- LogiMetrics A651/IJ Amplifier (8 GHz – 18 GHz)
- Model EAS-2 Test Lead Routing Standard (TLRS)
- Narda 50 Ω Termination (DC – 18 GHz)
- Narda Directional Couplers
- P/N SED38115052-301 Line Impedance Stabilization Network (LISN) (6A – 20 A)
- P/N SED38115052-303 Line Impedance Stabilization Network (LISN) (below 6 A)
- Philips PM5786B Pulse Generator
- Plotter
- Power Isolation Transformer
- Reference Magnet
- Rohde & Schwarz ESI26 Receiver System or Equivalent
- Rohde & Schwarz SMGU Signal Generator (100 kHz – 2160 MHz)
- Rohde & Schwarz SMP22 Signal Generator (2 GHz – 20 GHz)
- Rohde & Schwarz SMT03 Signal Generator (5 kHz – 3 GHz)

- RF Power Labs Amplifier (1-525 MHz)
- Solar 2055-1 DC Power Line Spike Generator
- Solar 6220-1 Isolation Transformer
- Solar 6512-106R Line Stabilization Capacitor (LSC)
- Solar 6550-1 Power Sweep Generator
- Solar 6552-1A Audio Amplifier
- Solar 7021-1 Phase Shift Network (AC power lines only)
- Solar 8282-1 Transient Pulse Generator
- Solar 8901-4-TS-100-BP (power lines carrying from 6 – 50 A)
- Solar 8901-4-TS-15-BP (power lines carrying less than 6 A)
- Solar 8904-4-TS-15-BP Line Impedance Stabilization Network
- Solar 9123-1N Current Probe (10 kHz – 500 MHz)
- Solar 9133-1 10 μ F Delta Capacitor
- Solar 9142-1N Injection Probe (2 MHz – 450 MHz)
- Solar 9225-0.5 Precision Resistor Assembly
- Solar 9229-1 Loop Sensor
- Solar 9230-1 Loop Antenna (30 Hz – 100 kHz)
- Solar 9233-50-TS-50-N Line Impedance Simulation Network
- Solar 9238-10-TS-50-BNC Line Impedance Stabilization Network
- Solar 9335-2 Multiple Port Coupling Device
- Solar 9354-1 Transient Pulse Generator with Frequency Modules
- Solar 9355-1 Pulse Generator
- Solar Transient Generator Model 6471-1
- Sorensen DCR 160-30T Power Supply
- Sorensen SRL 60-35 Power Supply
- Standard Gain Horn Antenna SA 12-12 (12 – 18 GHz)
- Standard Gain Horn Antenna SA 12-3.9 (3.9 – 5.8 GHz)
- Standard Gain Horn Antenna SA 12-5.8 (5.8 – 8.2 GHz)
- Standard Gain Horn Antenna SA 12-8.2 (8.2 – 12.4 GHz)
- Stoddart 93491-2 Conical Log Spiral Antenna (1000 – 10,000 MHz)
- Stoddart Horn Antenna 91888-1 (1.0 – 2.3 GHz)
- Stoddart Horn Antenna 91889-1 (2.3 – 4.4 GHz)
- Tektronix 754D Oscilloscope
- TESEO Fiberoptic Image 200 Color CCTV System
- TMD PTC6341 Amplifier (1 GHz – 2.8 GHz)
- Varian VTX6981F1 (8000 MHz – 12.4 GHz)
- Varian VZC6961K1DL (4000 MHz – 8000 MHz)
- Varian VZU6991K1D (12 GHz – 18 GHz)
- Zero Gauss Chamber

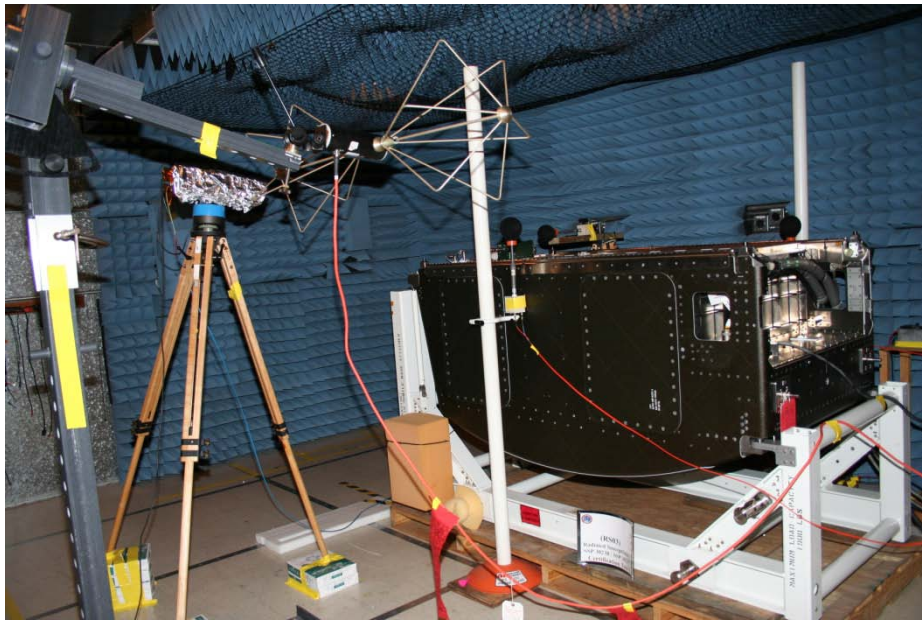
Appendix E Sample Test Configurations



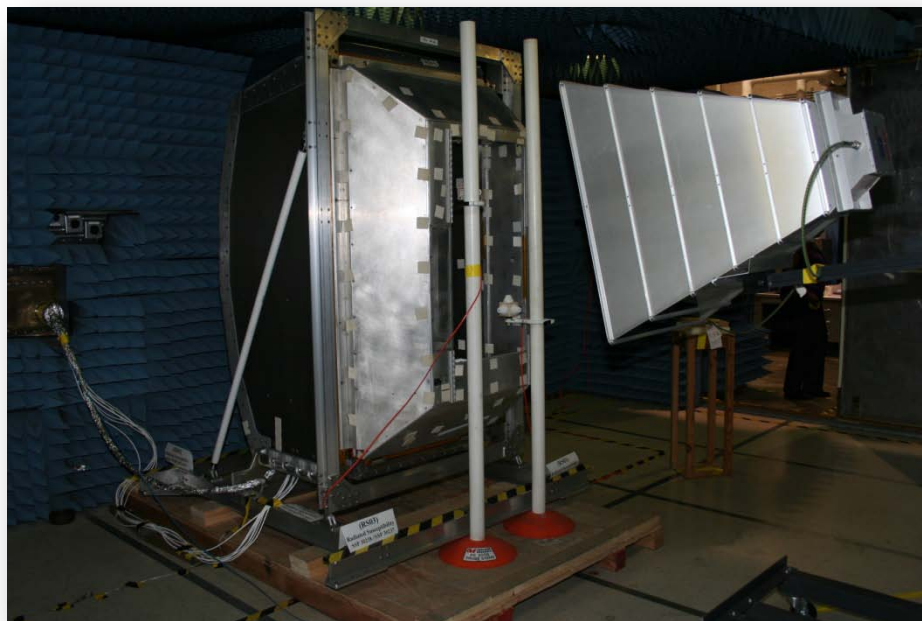
Electromagnetic Interference Test for Robonaut 2



Radiated Susceptibility for Potable Water Dispenser



Electromagnetic Interference Test for Treadmill 2



Radiated Susceptibility for Crew Quarters